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MYXOMYCETE DIVERSITY OF THE CHUYSKAYA DEPRESSION (ALTAY, RUSSIA)

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РАЗНООБРАЗИЕ МИКСОМИЦЕТОВ ЧУЙСКОЙ КОТЛОВИНЫ (АЛТАЙ, РОССИЯ)

Although myxomycetes are well known in the boreal forest (taiga) zone of Russia the species associated with this vegetation in south-eastern Siberia very little studied. Thus far only few attempts have been made to estimate the myxomycete diversity for local species inventory in Siberia (Taimyr Peninsula: Novozhilov et al., 1999; the southern part of the Krasnoyarsk territory: Kosheleva et al., 2008). Before this study only 41 species have been registered in the Altay Mts in Russia (Lavrov, 1929; Novozhilov, 1987; Barsukova, 2000). These data are based on published records, obtained mostly from field collections in different taiga communities of the central and north regions of the Altay Mts, especially at the Teletzkoe lake (the Altay State reservation). However, myxomycete biota of the arid regions of the southern Altay Mts has been not studied in Russia.

Material was collected during four weeks in August 2008 in central and east-southern Altay Mts. and adjacent region near Barnaul city. Other survey in this region has been done by K. A. Fefelov in 2002. The field studies were made to record or collect myxomycete sporocarps (fruit bodies) of myxomycetes and to obtain samples of various types of organic substrata to be used in the preparation of moist chamber cultures. Specific objectives of the study were (1) to obtain additional baseline data on myxomycete abundance and biodiversity in Russian Altay Mts (2) to determine the composition of the assemblages of species associated with all of the different microhabitats potentially available to myxomycetes in the different vegetation types being studied. This paper contains a part of this work relevant to the steppe and forest steppe habitats. Other portion of the data related to the different humid boreal types of vegetation (taiga) we plan to publish in another paper.

Material and methods

The Altay mountains in southern Siberia form the major mountain range in the western Siberia biogeographic region and is situated in the borderland between two subcontinents — Northern and Central Asia and stretches from 44°30′ to approximately 54° N and from

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80°30′(—82°)—92°30′(—98°E) (Fig. 1). It's a square of about 550 000 km^2 bound within the territories of Russia, Kazakhstan, China, and Mongolia. The climate of the Altay Mountain Country is sharply continental, and, because of absolutely open exposure to migrations of arctic air masses, is very severe. However, highly complicated relief considerably changes climatic conditions in different parts of the region. In general, the local climate is determined by the position of the locality regarding the altitudinal zonality, which differs in various parts of Altay (Kamelin et al., 2005). For example the average year temperature and precipitation in the Yaylu settlement near the Teletzkoe lake (Altay State Reservation, 480 m above sea level) is about 2.8 °C and 855—1200 mm correspondingly, whereas in the Chuyskaya depression near the Kosh-Agach settlement in the Kuray steppe (1760 m above sea level) is about –6.7 °C and 100—150 mm correspondingly.

Soils of Altay Mts is extremelly diverse (Kuminova, 1960). Complexity of the soil structure depends on zonal factors of relief and vegetation. Different variants of chestnut soils — from light and typical to dark on higher altitudes — are well developed in the are developed in southern regions of Altay Mts (mostly in Zaissan and Barun-Khurai depressions) and several parts of the Chuyskaya depression. These soils are often salty enough, and usually they are combined with typical solonchaks (Dergachova et al., 2007). The less podzoled variants are developed under the park Larix sibirica forests (and Pinus sibirica—Larix sibirica forests in the lowest part of subalpine steppe).

Diversity of natural conditions and considerable richness of flora lead to development in the Altay Mountain Country of a highly diverse vegetation. For the following ecological analysis of myxomycete assemblages only the main vegetation types were distinguished (Kamelin et al., 2005). Locality numbers written in bold in the following brief descriptions refer to Fig. 1; all sampled localities are assigned to the respective major vegetation types.

I. S t e p p e. Tuvinian-Mongolian steppe province is represented in Russian Altay Mts by a smaller part, whereas the main part of it stretches widely eastward in Mongolia. It inc-

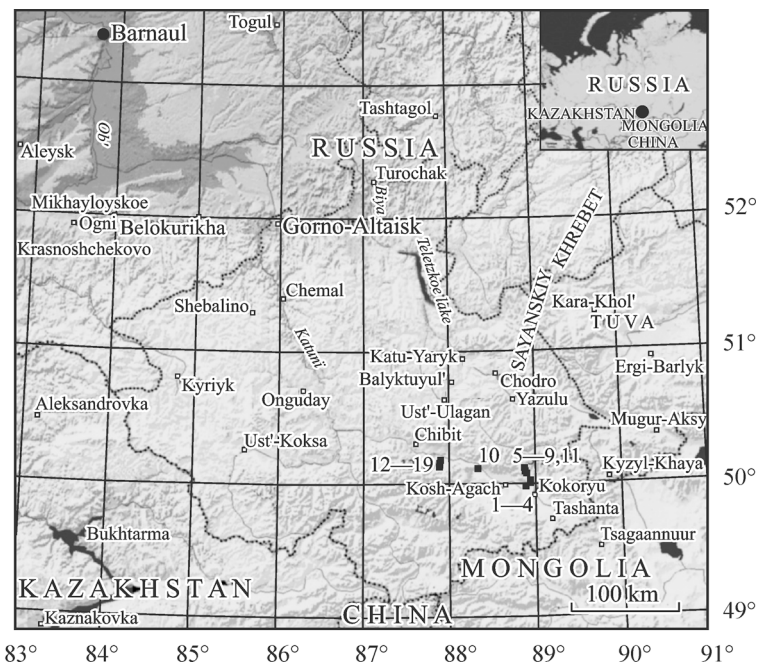

Fig. 1. Map of the Altay Mountain Country. Sampled localities are indicated by black rectangles. Lakes, rivers and valley forests are marked grey. Numbers refer to the localities listed in the text. A dotted black line indicates the border between countries. Insert: geographical position of the study area (delimited by the black circle). Source: Microsoft Encarta Reference Library, 2002 (modified) and the Gougle Earth (modified).

ludes Chuysky district of the Altay-Khangai subprovince of Altay-Sayan province (Kamelin et al., 2005). The main feature of the vegetation of the province is extremely low role of forest communities in the vertical zonality of the overwhelming majority of its ranges. Different variants of mountain steppes and shrub steppes prevail in the profile of altitudinal zonality of mountains of the province. In lower belts they are usually represented by the mountain variants of desert steppes in various combinations with specific semidesert and even North Gobian desert communities, desert-steppes and petrophytic desert-like steppes. In higher belts the steppes (mountain polydominant firm-bunch grass steppes), spread at the southern slopes, and meadow-steppes, combined with fragments of mesophilous shrub communities are to be met together with specific high mountain complexes.

There are a lot of regions with extremely low amounts of precipitations (Kuminova, 1960; Kharlamova, 2004), such as sites of extensive intermountain depressions (Chuyskaya «steppe» up to 200 mm with some localities of 110—150 mm). Communities of microtherm (rarely — mesotherm) xerophilous (predominantly — scleroxerophilous) herbs, first of all — bunch grasses, but also Artemisia sps. (e. g. A. frigida, A. gmelinii), shrubs (e. g. Caragana leucophloea, Spiraea hypericifolia) and Potentilla fruticosa near rivulets in swampy habitats, abundant set of dicotyls, especially from the Fabaceae family. Steppes, occupying diverse habitats, represent very heterogenous type of vegetation with montane-semidesert species including Chenopodium frutescens, Kochia krylovii, Potentilla astragalifolia, Astragalus sps., Stipa glareosa, Agropyron cristatum, species of Artemisia (Kamelin et al., 2005). **Kosh-Agach Loc. 1**: shallow SW-exp., slope with very dry feather-grass steppe, 1850 ± 50 m a. s. l., 49°58′46″ N 88°53′07″ E; **Loc. 2**: shallow SW-exp. slope with very dry shrub/feather-grass steppe, 2082 ± 50 m a. s. l., 50°00′05″ N 88°56′52″ E; **Loc. 3**: shallow saddle with very dry, desert-like steppe, 2084 ± 50 m a. s. l., 50°01′26″ N 88°57′10″ E; **Loc. 5**: heavily grazed steppe vegetation on gneiss, NE-exp. steep slope, 2159 ± 50 m a. s. l., 50°04′27″ N 88°54′21″ E; **Loc. 6**: extremely grazed dry steppe, 2030 ± 50 m a. s. l., 50°05′00″ N 88°54′28″ E; **Loc. 11**: cryophilous steppe with shrubs of Lonicera and Artemisia at a S-exp. slope, 2252 ± 50 m a. s. l., 50°07′16″ N 88°52′56″ E.

II. Mountain forest-steppe. An extent areas in Central and south-eastern Altay within of the steppe region there are localities where annual precipitations can reach 250—400 mm (Kharlamova, 2004) and expositional forest-steppe communities with larch can be developed. The only tree species is Larix sibirica form *s*ubalpine «park» larch forest, dark coniferous species are absent here, in exception with small areas with spruce (Picea obovata), developed within the river valleys of the northern slope, where also a stripe of Pinus sibirica in some sites of the timberline is present. **Kosh-Agach Loc. 4**: second-growth subalpine light coniferous forest (Larix sibirica) at a N-exp. slope, 2229 ± 50 m a. s. l., 50°04′16″ N 88°54′07″ E; **Loc. 7**: second-growth subalpine light coniferous forest (Larix sibirica), at a N-exp. slope, 2126 ± 50 m a. s. l., 50°05′46″ N 88°53′11″ E; **Loc. 8**: subalpine light coniferous forest (Larix sibirica) with overgrazed mountain steppe and scattered larch trees at a N-exp. slope, 2126 ± 50 m a. s. l., 50°05′46″ N 88°53′11″ E; **Loc. 9**: subalpine light coniferous forest (Larix sibirica) with extremely overgrazed mountain steppe and scattered larch trees, 2098 ± 50 m a. s. l., 50°05′56″ N 88°53′36″ E; **Kuray Loc. 10**: dry, grazed, opened mixed larch forest with P. laurifolia, with Lonicera sp. and Juniperus sabina in understory, 1750 ± 50 m a. s. l., 50°07′04″ N 88°20′42″ E; **Loc. 12**: subalpine light coniferous forest (Larix sibirica), steep N-exp. canyon with coniferous forest, with community of Comarum salessowii Bunge near rivulet, 1615 ± 50 m a. s. l., 50°08′11″ N 87°53′26″ E; **Loc. 15**: subalpine light coniferous forest (Larix sibirica), steppe meadows near a larch galery forest, Kokoria river, 1535 ± 25 m a. s. l., 50°10′3″ N 87°53′50″ E; **Loc. 17**: subalpine light coniferous forest (Larix sibirica), steppe meadows near a larch galery forest near a river, 1531 ± 25 m a. s. l., 50°10′21″ N 87°54′33″ E; **Loc. 18**: open steppe, mesophilous deciduous shrubs near a larch galery forest, community with Potentilla fruticosa and Salix sps., in swampy habitat, near river, 1530 ± 25 m a. s. l., 50°10′27″ N 87°54′00″ E; **Loc. 19**: transition belt from forest-steppe to coniferous mountain vegetation, shady coniferous forest with Picea obovata and Larix sibirica near river, 1700 ± 20 m a. s. l., 50°15′00″ N 87°51′00″ E.

A total of 76 substrate samples were collected for preparation of moist chamber cultures. These included: bark from living trees and shrubs (22 samples), plant leaf litter (1 samples), litter of grasses and herbaceous plants (9 samples), litter of coniferous cones (22 samples), litter of twigs (5 samples), samples of coarse woody debris (6 samples) of different trees, dung samples (22 samples) of various herbivores including cattle, camel, horse, sheep, goat and rodents.

Moist chamber cultures were prepared in the manner described by Härkönen (1977, 1981). All cultures consisted of moist filter paper in Petri dishes (10 cm in diam.) and were incubated under ambient light and at room temperature (ca 20—24 °C) for up to 90 days and examined for the presence of myxomycetes on six occasions (days 2—4, 6—8, 11—14, 20—22, 40—44 and 85—90). A record is defined herein as one or more fruiting bodies of a species originated from one culture.

Species diversity (alpha-diversity) was calculated using Shannon's diversity index $H' = -\Sigma P_i \log P_i$, where P_i is the relative abundance (the proportion of the total number of individuals or records represented by species) of a particular species (Magurran, 2004). For determination, sporocarps were preserved as permanent slides in lactophenol and/or glycerol gelatine, to distinguish between limeless and lime-containing structures. All microscope measurements and observations were made under a light microscope with differential interface contrast (DIC) Zeiss Axio Imager A1 with material mounted directly in polyvinyl lactophenol. Spore measurements were made of 10 spores from each of the collections. Air-dried sporocarps were studied with a stereomicroscope Zeiss Stemi 2000, and a JSM-6390 LA scanning electron microscope, at 10—15 kV in the Komarov Botanical Institute RAS (St. Petersburg). For the latter, specimens were mounted on copper stubs using double-sided sticky film and sputter-coated with gold. Species were identified according to Martin and Alexopoulos (1969) and various original descriptions from the literature, basically applying a morphospecies concept. Nomenclature follows that of Lado (2001) and Hernández-Crespo and Lado (2005) except for the two genera *Collaria* Nann.-Bremek., *Stemonitopsis* Nann.-Bremek. and the conserved names of several other genera (Lado et al., 2005) approved recently by the Committee for Fungi of the IAPT (Gams, 2005). Authorities are cited according to Kirk and Ansell (1992).

All species recorded are arranged alphabetically in the annotated list given below. The abbreviation 'cf.' in the name of a taxon indicates that it could not be assigned to this name without remaining doubts. One asterisk indicates a species recorded as new for the Altay Mts, whereas two indicate a new record for the Russia.

Names of vascular plants are those listed by Czerepanov (1995). After each name, an estimate of abundance is given in brackets. This estimate is based upon the proportion of a species in relation to the total number of records (74 identified to species level): **R** — rare (< 2 %, fewer than 2 record), **O** — occasional (2—4 %, 2 records), **C** — common (4—5 %, 3—4 records), **A** — abundant (> 5 % or more than 4 records). Abundance and the number of field records and records obtained in the moist chamber cultures given through «/» for a species is set in brackets. Next, the occurrence of a species in different vegetation types (indicated by Roman numerals) and microhabitats (indicated by letters) is listed. Six vegetation types were differentiated and described in the part «Study sites» (I — dry mountain steppe, II — mountain forest-steppe). Abbreviations for substrate types are b — bark of living trees and shrubs, d — dung of herbivorous animals, ll — leaf litter, lt — litter of twigs, lg — litter of grasses and herbaceous plants, w — large dead woody debris of trees and shrubs, c — litter of cones of conifeorus, g — living grasses, f — fruit bodies of fungi, m — mosses, s — soil. All study sites where a species was found are given in parentheses. Finally, the collection numbers are given. Voucher specimens are deposited in the collection of the first author in the fungal herbarium of the Komarov Botanical Institute of the Russian Academy of Sciences, Laboratory of Systematics and Geography of Fungi (LE), and in the collection of fourth author (KAF) in the Institute of Plant and Animal Ecology of the Russian Academy of Sciences. The string «...» indicates common species for which not all collection numbers were listed.

Results and discussion

Arcyria cinerea (Bull.) Pers. [**R**, 0/1] II: 1, b: 1 (Loc. 17). LE 255163. — This specimen with typical for var. *cinerea* ellipsoid grey sporothecae 1.5—2 mm in length obtained from the moist chamber culture on bark of Larix sibirica.

A. incarnata (Pers. ex J. F. Gmel.) Pers. [**C**, 3/0] II: 3, lt: 2, w: 1 (Loc. 19). KAF 3153, 3155, 3157. — One specimen was recorded on coarse woody debris of L. sibirica, another two specimens on litter of twigs of L. sibirica.

A. insignis Kalchbr. et Cooke [**R**, 0/1] II: 1, c: 1 (Loc. 17). LE 255179. — On litter of cones of L. sibirica, obtained in moist chamber culture.

A. pomiformis (Leers) Rostaf. [**O**, 1/1] II: 2, ll: 1, lt: 1 (Loc. 17, 19). LE 255171; KAF 3156. — On litter of needles and twigs of L. sibirica in moist chamber cultures. The sporocarps are yellow, and beige, ovoid. The capillitium is open, elastic consists of filaments 2—6 mkm in diam.; ornamentation of the capillitium in upper and lower part in the form of cogs and spinules. Spores yellowish in mass, 7—8 mkm in diam. with a few scattered verrucae.

Badhamia dubia Nann.-Bremek. [**O**, 0/2*] II: 2, b: 2 (Loc. 9, 10). LE 255137, 255589. — New for the Altay Mts. Both specimens obtained in moist chamber culture: one on bark of Artemisia gmelinii Weber ex Stechm. and another on bark of Populus laurifolia Ledeb. Sporocarps spherical, 0.5—1 mm in diam., pale bluish-grey, shining and iridescent. Capillitium a rather wide-meshed net of tubules, filled with white lime. Spore-mass black. Spores purple-brown, forming persistent clusters of 7—12 spores, the separate spores spherical or ovoid, 9—12 mkm diam., capped with spines or warts on the outside of the cluster and with a few low warts on the remainder.

Ceratiomyxa fruticulosa (O. F. Müll.) T. Macbr. [**C**, 3/0] II: 3, lt: 1, w: 2 (Loc. 19). KAF 3150, 3151, 3164. — Two specimens found on coarse woody debris of L. sibirica and one on litter of twigs, in shady situations in larch woodland near rivulet. This common species has been included, as it has traditionally been listed among myxomycetes, although it is related to another group of Eumycetozoa, the Protostelids (Olive, 1975). We use the conserved name for this species as proposed by Lado et al. (2005) and accepted by the IAPT (Gams, 2005).

Comatricha ellae Härk. [**A**, 0/7*] II: 7, b: 5, ll: 1, w: 1 (Loc. 9, 10, 12, 15, 17). LE 255136, 255155, 255141, 255583, 255585. — New for the Altay Mts. One of the commonest corticolous species in study area. It penetrates within forest steppe through arboreal intrazonal communities. This corticulous species is the commonest and most widely distributed species in the larch forests of southern Altay Mts. Specimens obtained in moist chamber cultures on bark of L. sibirica (2 records), Picea obovata Ledeb (2 records) and P. laurifolia (1 record) and on the decayed wood and litter of needles of L. sibirica. Differing from the closely related *C. nigra* by smaller size (0.5—1 mm), shorter stalk and a well-developed surface net on the capillitium and the coppery colour of sporocarps. Our specimens have all these characters excluding color of sporocarps; our sporocarps are duller then it was given in the type description.

C. nigra (Pers. ex J. F. Gmel.) J. Schröt. [**R**, 1/0] II: 1, lt: 1 (Loc. 19). KAF 3159. — On litter of twigs of L. sibirica.

Dianema mongolicum Novozh. [**R**, 0/1**] II: 1, b: 1 (Loc. 10). LE 255586. — New for Russia. Prominent characters of this species is stiff capillitium that has rounded or elliptic acetabuliform swellings of 1—10 mkm in diam., a thick peridium appearing opaque yelowish-brown that is impregnated with refuse material, and pale yellow, spinulos spores (9.5—)10.0—10.5(—11.0) mkm in diam. This rare corticolous species has been described from Mongolia (Novozhilov, Golubeva, 1986) on bark of Populus diversifolia and recently was found on bark of Artemisia tridentata in Arizona (David Mitchell, pers. comm.). All of our sporocarps, were found on the bark of Populus laurifolia in moist chamber cultures near with Russian-Mongolian border in the dry mixed opened larch-poplar forest with scattered shrubs of Lonicera sps. and Juniperus sabina. This locality situates about 500 km north-western of the type locality and is similar by the climatic characters with the type locality.

Didymium anellus Morgan [**R**, 1/0*] II: 1, w: 1 (Loc. 19). KAF 3161. — New for the Altay Mts. On coarse woody debris of L. sibirica.

D. difformе (Pers.) Gray [**R**, 0/1*] II: 1, w: 1 (Loc. 4). LE 255168. — New for the Altay Mts. On coarse woody debris of L. sibirica.

D. quitense (Pat.) Torrend [**R**, 0/1*] II: 1, d: 1 (Loc. 4). LE 255177. — New for the Altay Mts. This specimens came together with other coprophilic species *Kelleromyxa fimicola* and *Licea tenera* from weathered dung of horse cultivated in moist chamber. Specimen has numerous scattered sporocarps in the form of pulvinate, sporangia 0.5—1.5 mm in diam., white or cream. Peridium double, outer layer shell-like, composed of compacted crystals. Inner layer of peridium membranous, bluish. Capillitium sparse consists of short very pale by transmitted light threads with dark expensions. The spore size of specimens matches well *D. quitense* as described by Martin and Alexopoulos (1969), with very purplish brown by transmitted light spores (10—)11—13(—14) mkm in diam. The spore densely spinulose with the spines more or less united to form an imperfect reticulate pattern. However, *D. quitense* is described with strongly warted spores, which leaves some doubt as to the placement of this specimen in this taxon.

Echinostelium colliculosum K. D. Whitney et H. W. Keller [**C**, 0/3*] II: 3, b: 3 (Loc. 10). LE 255111, 255132. — New for the Altay Mts. Typical corticuloid species, on bark of trees, shrubs and dwarf-shrubs, in particular Lonicera tataricum L., P. laurifolia, Picea obovata. Our specimens include large colonies of shining, pinkish or colourless, very small (60—100 mkm in height) sporocarps, spores clustered in groups of 20—50, bearing discs at points of spore-to-spore contact, always with a spore-like columella. The articular surfaces of spores of *E. colliculosum*, are less prominent than those of *E. coelocephalum*, and are not of uniform thickness (Whitney, 1980).

E. corynophorum K. D. Whitney [**O**, 0/2**] II: 2, w: 1, c: 1 (Loc. 9). LE 255109. — This is a new record for Russia. Both specimens obtained in moist chamber cultures, one on litter of cones of L. sibirica and another on coarse woody debris of larch. It was first reported from the California by Whitney (1980) on bark of Juniperus occidentalis. All of our collections were obtained on slightly acidic substrate (mean pH 6.03 ± 0.07) including bark, cones and wood of Larix sibirica and Picea obovata in moist chamber culture and exhibit the typical characters of this species. This species is close to *E. brooksii*, from which it is separated by the light lenticular columella in transmitted light and spores with circular areas at points of spore-to-spore contact.

E. cribrarioides Alexop. [**R**, 0/1*] II: 1, b: 1 (Loc. 10). LE 255133. — New for the Altay Mts. On bark of Lonicera tataricum in moist cnamber culture. The overall habit of this specimen best fits that of *E. cribrarioides*, the capillitium forms a complete globose net with large meshes which is unique for this genus.

E. minutum de Bary [**O**, 0/2*] II: 2, b: 1, c: 1 (Loc. 9, 12). LE 255142. — New for the Altay Mts. Both specimens obtained in moist chamber cultures on bark of Comarum salessowii and another litter of cones of Picea obovata.

E. papillatum (Pers.) Rostaf. [**R**, 1/0] II: 1, lt: 1 (Loc. 19). KAF 3149. — On litter of twigs of L. sibirica.

Kelleromyxa fimicola (Dearn. et Bisby) Eliasson [**C**, 0/3*] I: 1, II: 2, d: 3 (Loc. 12, 13, 18). LE 255160, 255169, 255175. — New for the Altay Mts. and the second record of the species for Russia. It was only previously known on dung of herbivorous animals from the several localities in desert of the Caspian lowland (Novozhilov et al., 2006). All specimens were found in the driest part of the Altay Mts — the Chuyskaya «steppe». This species has a strong preference for dung. The distinguishing characteristics of this species are shiny black, spindle-shaped sporangia; rather thick, cartilaginous peridium often dehiscent by the preformed suture; simple capillitium consists of solid threads and spores with thick wall and ornamented by scattered sometimes aggregated large spines.

Leocarpus fragilis (Dicks.) Rostaf. [**R**, 1/0] II: 1, lt: 1 (Loc. 19). KAF 3152. — This specimens found on litter of twigs of L. sibirica, in shady situations in larch woodland near rivulet. As well as *C. ellae* this species penetrates within forest steppe and steppe through arboreal intrazonal communities.

Licea parasitica (Zukal) G. W. Martin [**O**, 0/2*] II: 2, b: 1, lt: 1 (Loc. 10, 17). LE 255135, 255165. — New for the Altay Mts. Both specimens obtained in moist chamber culture, one — on bark of P. laurifolia and another on litter of twigs of A. gmelinii.

L. tenera E. Jahn [**R**, 0/1] I: 1, d: 1 (Loc. 5*) mc 17080. — New for the Altay Mts. Obtained in moist chamber cultures together with *K. fimicola* and *D. quitense* on dung of horse. This species approaches *Perichaena liceoides* in habit and substrate preferences. Our specimens of *L. tenera* have a peridium in which the outer layer lacks the granular deposits as found in *P. liceoides* but is characterized by amorphous deposits. Spores minutely roughened (asperulate), requiring oil immersion to observe, spinulose (delicately spiny) under SEM, spines 0.2—0.3 mkm high. This is another example of a strictly coprophilous myxomycete.

L. testudinacea Nann.-Bremek. [**R**, 0/1*] II: 1, ll: 1 (Loc. 17). LE 255164. — New for the Altay Mts. This specimen was found in a moist chamber culture on the needles of L. sibirica. *Licea testudinacea* appears to be most closely related to *L. minima* and *L. chelonoides*. It is distinguished from *L. minima* by the darker, more olive and not rusty-coloured spore mass. In the latter species, the spores are always reddish brown by transmitted light and the peridium has two or three layers. *L. chelonoides* differs by having dull black sporocarps not shining when dry, platelet margins with 5 or more rows of tubercles, and spores measuring 15—18 mkm in diam.

Lycogala epidendrum (L.) Fr. [**R**, 1/0] II: 1, w: 1 (Loc. 19). KAF 3162. — On coarse woody debris of L. sibirica, in shady situations in larch woodland near rivulet. As well as some other lignicolous species, *L. epidendrum* penetrates within forest steppe and steppe through arboreal intrazonal communities.

L. exiguum Morgan [**R**, 1/0*] II: 1, lt: 1 (Loc. 19). KAF 3163. — New for the Altay Mts. On litter of twigs of L. sibirica. Our specimen consists from several small subglobose aethalia, 2—4 mm in diam. with typical characters of this inconspicuous species. Cortex yellow-brown, thickly covered with dark, purplish-brown or black scales, these pulvinate at first with homogeneous contents, tending to become divided internally into numerous chambers and finally appearing flat and tessellate. Pseudocapillitium composed of colourless or yellow branching tubules arising from the middle cortex layer, often smooth at the base, roughened or transversely wrinkled elsewhere, 2—10 mkm in diam. Spores nearly colourless, marked by faint, irregular warts and lines, sometimes appearing nearly smooth, 4.5—6 mkm in diam.

Macbrideola oblonga Pando et Lado [**R**, 0/1*] II: 1, b: 1 (Loc. 10). LE 255129. — New for the Altay Mts. Obtained only one time in moist chamber culture on bark of P. laurifolia collected in extremely arid locality of the Chuyskaya steppe. The oblong shape of the sporotheca and the presence of free spores differentiate this species of *Macbrideola*. Comparisons with material obtained from Kazakhstan (Schnittler, Novozhilov, 2000; Zemlianskaia, Adamonyte, Krivomaz and Novozhilov, unpubl. data), Mongolia (Novozhilov et al., 2008), the Orenburg area of Russia (Novozhilov, unpubl. data), the Colorado Plateau of the western United States (Novozhilov et al., 2003) allow us to assign our specimens to *M. oblonga*. Common in arid regions.

Paradiacheopsis fimbriata (G. Lister et Cran) Hertel ex Nann.-Bremek. [**C**, 0/4*] II: 4, b: 3, c: 1 (Loc. 4, 7, 9, 17). LE 255156, 255154... — New for the Altay Mts. Our material includes numerous sporocarps obtained in moist chamber cultures, with typical capillitial threads finishing by swollen and club-shaped tips. This species definitely connected with extremly acidic bark of L. sibirica (3.62 ± 0.41), but can be found on litter of cones of this tree also (1 record).

Perichaena depressa Lib. [**R**, 0/1*] II: 1, d: 1 (Loc. 17). LE 255180. — New for the Altay Mts. Obtained in moist chamber culture on dung of sheep.

P. luteola (Kowalski) Gilert [**O**, 0/2*] I: 1, II: 1, d: 2 (Loc. 10, 13). LE 255170... — New for the Altay Mts. Both specimens obtained in moist chamber cultures on dung of horse. The distinguishing characters of this species are the transparent thin peridium with smooth inner surface, olive shiny globose sporocarps with a bright yellow spore mass that looks as a dense globe within the sporocarp when observed with a dissecting microscope. Capillitium yellow, composed of a network of branched and anastomosed tubules 1—4 mkm in diam., with

a few free ends that are weakly attached to the peridium. This is a strictly coprophilous myxomycete.

P. vermicularis (Schwein.) Rostaf. [**R**, 0/1*] I: 1, ll: 1 (Loc. 2), mc 17088. — New for the Altay Mts. The specimen came from leaf litter cultivated in moist chamber.

Physarum cinereum (Batsch) Pers. [**O**, 0/2] II: 2, b: 1, lt: 1 (Loc. 17). LE 255166, 255167. — One specimen from litter of twigs of A. gmelinii, and another from bark of living shrubs of Juniperus communis L.

Ph. decipiens M. A. Curtis [**A**, 0/5*] I: 1, II: 4, b: 1, ll: 2, lt: 1, lg: 1 (Loc. 9, 11, 17, 18). LE 255138, 255199, 255152, 255153, 255580. — New for the Altay Mts. This species occupies different substrates including leaf litter (1 record), litter of twigs (1 record) and bark of living A. gmelinii (1 record), litter of J. sabinii (1 record) and litter of grasses.

Ph. notabile T. Macbr. [**A**, 0/10] I: 4, II: 6, b: 2, d: 2, ll: 2, lt: 1, lg: 3 (Loc. 2, 6, 10, 13, 14, 17, 18). LE 255587, 255230, 255134, 255159, 255116, 255130, 255131, 255593, 255581... — This species as a previous species occupies different kinds of substrates: leaf litter (1), dung of herbivorous animals (2), bark of living trees (2), litter of twigs (1), litter of grasses (3), and litter of needles of J. sabina (1). According the literature (Martin, Alexopoulos, 1969), *P. notabile* is reported mostly on wood in temperate and boreal deciduous and coniferous forests and characterized by dark, limeless cupulate base of sporotheca and abundant capillitium. This species is reported from the Altay State Reservation in the Central Altay (Barsukova, 2000). Specimens from arid regions of southern Altay obtained in moist chamber cultures fit to forms recently described from arid regions of western Kazakhstan (Schnittler, Novozhilov, 2000) and the Caspian Lowland (Novozhilov et al., 2006) and Mongolia (Novozhilov et al., 2008).

Trichia favoginea (Batsch) Pers. [**O**, 2/0] II: 2, b: 1 (Loc. 19). KAF 3158, 3166. — One specimen found in the field on bark of coarse woody debris of L. sibirica, another — on old fruit bodies of poliporoid fungi developed on log in shaded habitat, near rivulet. This is example of lignicolous species having a wide range and penetrated within of steppe zone through habitats with arboreal vegetation.

T. varia (Pers. ex J. F. Gmel.) Pers. [**C**, 3/0] II: 3, lt: 1 (Loc. 19). KAF 3154, 3160, 3165. — This boreal lignicolous species penetrated far to steppe zone through habitats with arboreal vegetation. Two specimens found on old fruit bodies of poliporoid fungi developed on log in shaded woodland, and one specimen on litter of twigs, in shaded habitat, near rivulet.

Since only 18 records were obtained in the field almost all data of this survey from steppe and forest-steppe originate from moist chamber cultures (Fig. 2). A total of 56 records

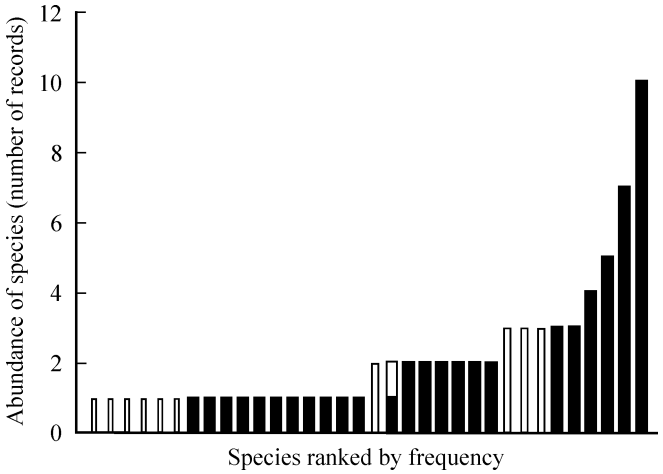

Fig. 2. Frequency distribution of all 73 records of 34 species (records from the field and from moist chamber cultures) for the Altay Mts. Grey bars represent species found in the field. Dark sectors of the bars indicate records obtained from moist chamber cultures.

were obtained from 76 moist chamber cultures (excluding 12 records of non-fruiting plasmodia) and 18 field collections of fruit bodies, representing 34 species from 16 genera and 7 families. Overall, the myxomycete diversity and species richness from the Chuyskaya steppe were found to be relatively moderate (H′ = 3.25, 34 species). However, 17 species were classified as rare for whole studied area. Records from the field and from moist chamber cultures mostly complement each other (Fig. 2). Eleven species were observed in the field, whereas 24 species were registered in moist chamber cultures. Only *Arcyria pomiformis* was found in the field as well as in moist chamber culture.

Only two common species found in the field (4 records) and confined to wood debris and old fruit bodies on decayed wood was *Trichia varia* and *Ceratiomyxa fruticulosa*. Other lignicolous species *Trichia favoginea*, *Comatricha nigra*, *Enerthenema papillata*, *Lycogala epidendrum*, *L. exiguum* were rare for this region and present element of myxomycete biota of taiga communities in the Altay Mts. All of these species are widely distributed and often abundant in temperate deciduous forests and are also well known from the taiga. This suggests that the zonal limits of myxomycete distribution are relative. In the forest communities they are found in a variety of microhabitats in watersheds and in damp depressions. In the steppe zone they also occur in appropriate situations in intrazonal arboreal habitats near rivulets where there is a rich supply of coarse woody debris.

The diversity of myxomycetes differs considerably in forest steppe arboreal habitats and in zonal open dry steppe and desert habitats (Table 1). The high species richness in intrazonal habitats is due primarily to the general rarity of lignicolous species and litter-inhabiting species in steppe. As the specificity of the environment increases with the prevailing conditions of the open zonal habitats of steppe and desert, the number of rare species decreases and the proportion of abundant species increase. This follows the pattern that species domi-

Table 1

Statistical data for steppe and forest steppe vegetation types of the southern Altay Mts (Russia)

Parameter	I	II
Mean elevation, m	1945	1657
Mean annual precipitation, mm	110	300
Substrate pH, mean ± SE	7.21 ± 0.03	6.79 ± 0.03
Sampled localities	8	10
[a]Rec (fc/mc)	9 (0/9)	65 (18/47)
Number of MC	19	57
MC positive, %	52.6	56.1
[b]Rec	13	60
S/MC	0.68	1.05
S (fc/mc)	6 (0/6)	32 (11/22)
G	4	16
S/G	1.5	2.0
H′	1.5	3.2
D	0.26	0.05

Notes. Vegetation types (see details in the part «Material and methods»): I — desert steppe/dwarf shrub communities of the plains, treeless landscapes; II — mountain forest-steppe with subalpine «park» larch forest and deciduous tall shrub communities; Mean elevation calculated for all studied localities; Mean annual precipitation calculated for all studied localities; [a]Rec — records of determined species including field collections (fc) and obtained from moist chamber cultures (mc); [b]Rec — records obtained only from moist chamber cultures including undetermined taxa and non-fruiting plasmodia; MC — number of moist chamber cultures; S — number of species including found in the field (fc) and moist chamber cultures (mc); G — number of genera; H′ — Shannon's index; D — Simpson's index.

nance in zonal treeless steppe habitats with extreme conditions is higher (D = 0.26) than in the more stable and diverse habitats of forest steppe habitats where lignicolous myxomycetes can find shelters and substrates in shaded habitats e. g. near rivulets (D = 0.05).

The most abundant species in treeless steppe and forest steppe habitats (> 6 % of all 76 records) was *Physarum* cf. *notabile* (ubiquitous species). Other common species (3—4 % of all records) were *Arcyria incarnata*, *Comatricha ellae*, *Echinostelium colliculosum*, *Paradiacheopsis fimbriata*, and *Kelleromyxa fimicola* (obligate coprophilic species). The total of 34 taxa includes, 2 species which are new records for Russia: *Echinostelium corrynophorum* and *Kelleromyxa fimicola* and 21 species new for the Altay Mts.

Interestingly, *Fuligo cinerea*, which was found only once in the Altay Mts. in taiga community of the Altay Mts. (Barsukova, 2000), and was not registered in the Chuyskaya steppe. In contrast it was recently reported as a common species in the dry steppe and desert regions of the Caspian lowland in Russia and western Kazakhstan (Novozhilov et al., 2006). This fact is corresponded with data about distribution of this species in Mongolia and eastern Kazakhstan, were it is very rare (Novozhilov et al., 2008). This fact supports a hypothesis about moderate endemism of some species within Eurasian arid area.

The majority of the species of the Altay Mts. have polyzonal ranges and widely distributed. About 20 % of the 34 species recorded in this study can be regarded as regularly occurring at the steppe and desert regions. These are *Dianema mongolicum*, *Echinostelium colliculosum*, *Kelleromyxa fimicola*, *Macbrideola oblonga*, *Physarum* cf. *notabile*. The steppe and forest steppe communities of the Chuyskaya depression are relatively rich in *Physaraceae* (21 species), *Trichiaceae* (16 species), *Stemonitidaceae* (14 species), but species of *Cribrariaceae* which are widely distributed in taiga forests are absent.

Both species richness and diversity varied considerably within groups of substrates (Table 2) and decreased from bark of living plants (14 species, H′ = 2.45) and litter of twigs (12 species, H′ = 2.46), to the dung of herbivorous and leaf litter (6 species, H′ = 1.20), litter of cones of coniferous (4 species, H′ = 1.33) to the coarse of woody debris (7 species, H′ = 1.17).

The most abundant corticolous species were *Comatricha ellae* (5 records on bark of 7 registered), *Echinostelium colliculosum* and *Paradiacheopsis fimbriata* (3 records on bark

Table 2

Statistical data for all investigated substrates in steppe and forest steppe vegetation types of the southern Altay Mts (Russia)

Substrates	[a]Rec	MCs	MC positive, %	[b]Rec	S/MC	S	G	S/G	H′	D
b	19	22	60	27	1.23	14	12	1.17	2.45	0.10
d	9	22	50	12	0.55	6	5	1.20	1.52	0.23
ll	7	1	50	11	1.00	6	5	1.20	1.55	0.22
lt	12	5	100	3	3.00	12	9	1.33	2.37	0.10
lg	4	9	40	6	1.20	2	2	1.00	0.56	0.63
w	5	6	30	6	0.67	7	6	1.17	1.61	0.20
c	4	22	50	5	0.83	4	3	1.33	1.39	0.25
g	0	0	0	0	0	0	0	0	0	0
f	3	0	0	0	0	2	1	2.00	0.64	0.56
m	0	0	0	0	0	0	0	0	0	0
s	0	0	0	0	0	0	0	0	0	0

Notes. b — bark of living plants; d — dung of herbivorous animals; ll — leaf litter; lt — litter of small twigs; lg — litter of grasses and herbaceous plants; w — coarse woody debris; c — litter of coniferous cones; g — living grasses and herbaceous plants; f — fruit bodies of fungi; m — mosses and liverworts; s — soil. Other abbreviations as given in the Table 1.

of 3 registered) and *Badhamia dubia* (2 records on bark of 2 registered). All this species were registered only in moist chamber cultures. The dominant litter-inhabiting forms was *Physarum notabile* (3 records of total 10 registered), *Trichia botrytis* (15), *Didymium squamulosum* (22), *Hemitrichia pardina* (31) and *Didymium difforme* (36).

The most specific myxomycete assemblage occurs on dung of herbivorous animals. This group of species included typical litter-inhabitants such as *Didymium quitense* (1 record), and some common species which are known to tolerate a wide range of ecological amplitude and can sometimes utilize dung, such as *Physarum notabile* (2 records), obligate coprophils were: *Licea tenera* (1 record), *Perichaena lutea* (2 records), *Kelleromyxa fimicola* (3 records). Wood-inhabiting (lignicolous) myxomycetes represented the poorest myxomycete assemblage in the steppe and forest steppe communities of the Chuyskaya depression. Two species (*Ceratiomyxa fruticosa*, *Lycogala epidendrum*) were found only on this substrate in shadowed habitats near rivulets and a few species are known to sporadically (1 record) occur in moist chamber cultures such as *Didymium anellus*, *D. diforme*, *Comatricha ellae*, *Arcyria incarnata*, *Echinostelium corynophorum*.

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РЕЗЮМЕ

Целью данной работы было изучение таксономического и экологического разнообразия миксомицетов в условиях сухих степей и горной лесостепи юго-восточного Алтая в Чуйской котловине. Было зарегистрировано 74 образца плодовых тел миксомицетов, из которых 56 получены во влажных камерах и 18 собраны в поле. Всего было найдено 34 вида, относящихся к 16 родам и 7 семействам. Семнадцать видов были отнесены к группе редких на данной территории. Одиннадцать видов были найдены в поле, тогда как 24 вида были изолированы методом влажной камеры. В аннотированном списке приведены сведения о морфологии, экологии и распространении видов, дана характеристика таксономического и экологического разнообразия, описание особенностей их распространения. Выявлены некоторые тренды в изменении разнообразия миксомицетов на различных субстратах. Среди 7 групп субстратов (кора живых деревьев и кустарников, опад листьев, опад веточек, опад шишек хвойных, опад трав, остатки гнилой древесины, помет растительноядных животных) на коре формируется наиболее разнообразная и богатая биота миксомицетов, тогда как на выветрившемся помете растительноядных животных обитает наименьшее число видов, однако с наибольшей специализацией к данному субстрату. Среди 21 вида, новых для Алтая на территории России, два (*Dianema mongolicum* и *Echinostelium corynophorum*) отмечены впервые.

Ключевые слова: биоразнообразие, экология, слизевики, Алтай, горная лесостепь, сухие степи.

S U M M A R Y

The primary objective of the present study was to obtain data on taxonomical and ecological diversity of myxomycetes (plasmodial slime moulds) in the dry steppe communities of the south-eastern Altay. A total of 56 records were obtained from 74 moist chamber cultures (excluding 12 records of non-fruiting plasmodia) and 18 field collections of fruit bodies, representing 34 species from 16 genera and 7 families. Seventeen species were classified as rare for the whole studied area. Eleven species were observed in the field, whereas 24 species were registered in moist chamber cultures. Taxonomic descriptions and ecological observations of rare and/or tentatively new taxa found in the study area are provided in the annotated checklist. Among seven different groups of substrata (bark of living trees and shrubs, ground leaf litter, ground litter of twigs, litter of coniferous cones, litter of grasses, coarse wood debris and dung of herbivores) diverging trends in species richness and substrate specificity of the species were found: bark of living plants had the richest myxomycete biota, dung the poorest but most specific myxomycete assemblage. Twenty one species are herein first reported for the Altay Mts and 2 are new records for Russia: *Dianema mongolicum* и *Echinostelium corynophorum*.

Key words: biodiversity, ecology, slime moulds, Altay mountain forest steppe, dry steppe.